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DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

ABSORPTION OF METHANE AND OTHER GASES BY COAL

BY

S. H. KATZ

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ABSORPTION OF METHANE AND OTHER GASES BY COAL.

By S. H. Katz.

INTRODUCTION.

That bituminous coal absorbs carbon dioxide with great readiness Richters[a] found in 1870. He showed further that the carbon dioxide may be given up by the coal when in a vacuum. Prior to that time the absorption of oxygen by coal at ordinary temperatures was known.

Before the international conference of mine experiment stations held in Pittsburgh, Pa., September, 1912, Thiessen,[b] chemist of the Bureau of Mines, presented a paper showing that bituminous coal dust absorbed various gases when exposed to them. According to Thiessen, 1 gram of an Illinois coal, passed through a 200-mesh sieve, absorbed 5.6 c. c. of natural gas.

Le Prince-Ringuet[c] concluded that a gram of powdered coal that contained 13.5 per cent of volatile matter absorbed 1.9 c. c. of methane from a gas of this composition:

Composition of gas used by Le Prince-Ringuet.

	Per cent.
Methane (CH_4)	89.0
Oxygen (O_2)	1.2
Nitrogen (N_2)	9.2
Carbon dioxide (CO_2)	0.6

Similar experiments were recently described by Graham.[d]

At the suggestion of G. S. Rice, chief mining engineer of the Bureau of Mines, the author of this paper made a study of the absorption of methane by bituminous coal. A better understanding of the nature of the absorption promised to be useful in mining technology. It might help to explain the loss of methane by coal exposed to the air;[e] it might serve to explain in part the influence of methane on coal-dust explosions; and it might prove of value in problems dealing with coal-mine gases.

---

[a] Richters, E., Ueber die Veränderungen welche die Steinkohle beim Lagern an der Luft erleiden: Dingl. poly. Jour., Bd. 195, 1870, pp. 315–331.

[b] Thiessen, R., Results of examination of coal dust under the microscope: Bull. 82, Bureau of Mines, 1913, pp. 56–58.

[c] Le Prince-Ringuet, F., Expériences sur l'absorption des gaz par la houille: Compt. rend., t. 158, 1914, pp. 573–576.

[d] Graham, J. I., Occlusion of gases by coal: Coll. Guard., vol. 112, 1916, p. 513.

[e] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Tech. Paper 2, Bureau of Mines, 1911, 14 pp.

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METHODS USED IN EXPERIMENTS.

Two methods of experiment were employed. They are designated throughout the paper as the experiment with air and the experiment with an atmosphere of nitrogen.

In the experiment with air the coal was put into a large bottle containing air and methane was added. At intervals for a period of five weeks thereafter samples of the atmosphere in the bottle were taken and analyzed. During the experiment the coal was exposed to the action of the oxygen of the air, and simultaneously to the action of the admixed methane, the conditions thus representing in part at least those under which coal-mine dust is exposed to mine air.

In the experiment with an atmosphere of nitrogen the coal was put into a small bottle and very pure nitrogen introduced. The bottle was connected to a burette filled with methane. The gases in the bottle and burette were quickly mixed and the change in volume of the gas read from the burette as the absorption proceeded.

EXPERIMENTS WITH AIR.

APPARATUS.

A 20-liter bottle was closed with a rubber stopper through which a millimeter tube extended to the center of the bottle. By means of a three-way cock sealed to the tube above the stopper, the gas in the bottle could be connected with a mercury manometer, or samples of gas could be withdrawn for analysis. One side of the manometer was open to the air.

COAL.

Five selected lumps of Pittsburgh coal of about 1 kilogram each were taken from different heights on a new face in the experimental mine of the Bureau of Mines at Bruceton, Pa. The next morning the lumps were crushed, a composite was made of equal parts of each, and a portion was removed for an analysis. The air-drying loss of the sample was 0.9 per cent. The analysis of the air-dry coal resulted as follows:

Analysis of air-dry coal from experimental mine.

[Analyst, A. C. Fieldner.]

	Per cent.
Moisture	1.61
Volatile matter	37.67
Fixed carbon	55.38
Ash	5.34
	100.00
Sulphur	1.15

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The rest of the coal was put into ball mills and ground. At intervals during the grinding the coal was screened and what passed through a 200-mesh sieve was kept from contact with the air of the room. The next morning two portions of 400 grams each of the coal were taken. One portion was put into a 20-liter bottle for immediate experiment. The other was put into a large beaker, covered with a cover glass to prevent addition of dust, and left exposed to the room air. During this exposure the coal might evolve methane, be oxidized, and lose some of its water.[a] These changes might modify its absorbing properties.

GAS.

In the experiment with both the fresh and exposed coal samples, the bottle contained air when the coal was introduced. The apparatus was then assembled and the top of the bottle and the rubber stopper were sealed over with Khotinsky cement to prevent leaks. After an interval of about 10 minutes to allow the atmosphere in the bottle to come to the same temperature, and pressure, as the room air, a measured amount of methane of known purity was added to the air in the bottle.

ANALYSES.

About four hours' time was allowed for the diffusion of the methane to all parts of the bottle. A mercury-filled gas pipette was connected to the bottle, 10 c. c. of gas was withdrawn through the connecting tubes and wasted, in order to fill the tubes with gas from the bottle, and then 42 c. c. of gas was withdrawn for analysis. For every analysis made a like amount of gas was withdrawn, the total being 52 c. c. Immediately before and after the withdrawal of the samples, the room temperature and barometric pressure were recorded. The samples were analyzed with a Haldane apparatus, the contraction on ignition and the carbon dioxide produced being recorded, and the methane and carbon monoxide being calculated. The other constituents of the gas were determined in the usual manner.

COMPUTATIONS.

In Table 1 the data obtained from the fresh coal are given; in Table 2 are the data from the exposed or oxidized coal. From the figures in these two tables an account is made of the volumes of each constituent of the gas in the bottle, water vapor being neglected. A statement of the volumes is given in Tables 3 to 7. Figures 1 and 2 show graphically the relations between time and the partial volumes of the various constituents of the gas as given in these tables. The analyses represented in Tables 1 to 7 were made by the author.

[a] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Tech. Paper 2, Bureau of Mines, 1911, 14 pp.

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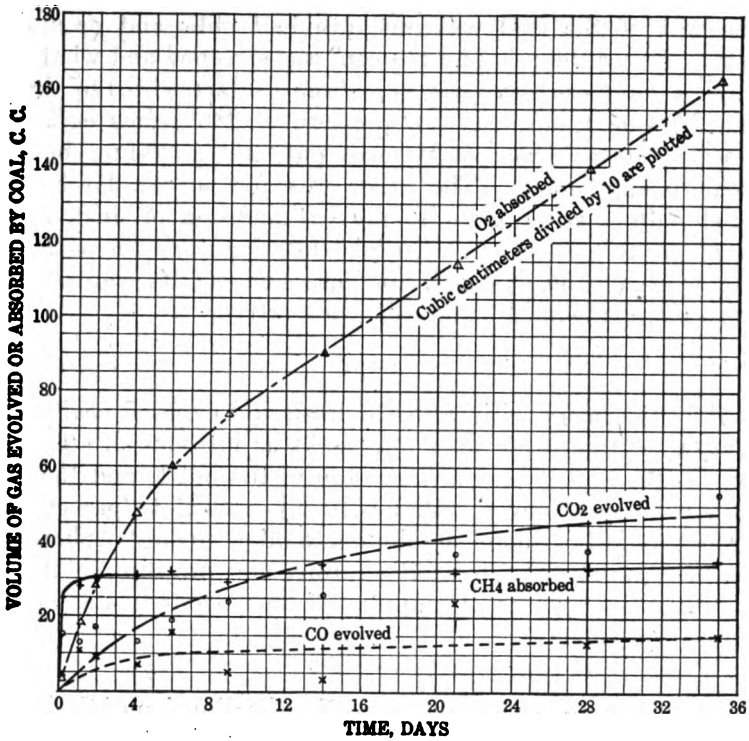

FIGURE 1.—Curve showing relations between time and volumes of gases absorbed or evolved by fresh coal, experiment with air.

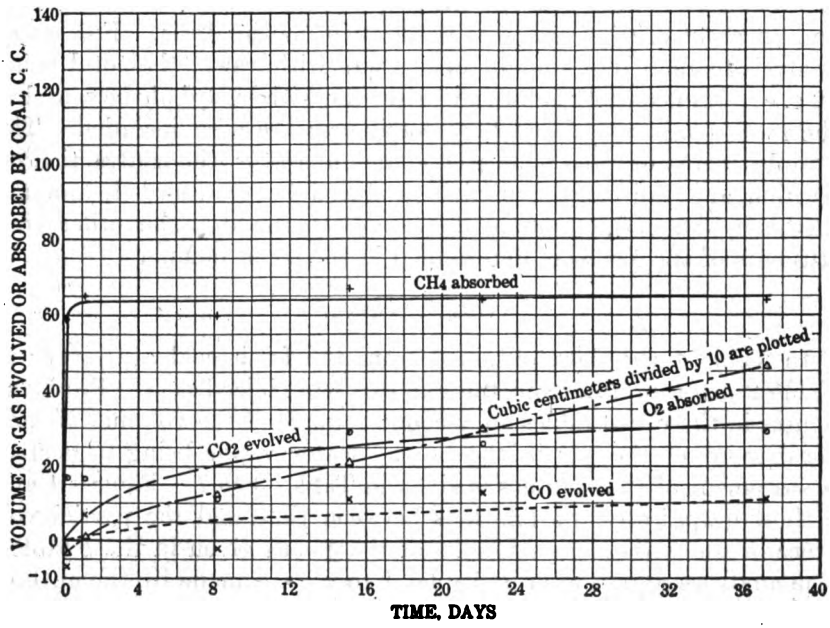

FIGURE 2.—Curve showing relations between time and volumes of gases absorbed or evolved by air-dry coal, experiment with air.

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TABLE 1.—*Primary data from fresh coal, in experiment with air.*

Analysis No.	Time elapsed (days).	Volume of gas at 760 mm. and 0° C.		Composition of gas.				
		Before taking sample.	After taking sample.	CO_2.	CO.	CH_4.	O_2.	N_2.
		Liters.	*Liters.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
0F[a]	0.000	18.435	.....	0.03	0.00	2.91	20.31	76.75
1F	.184	18.262	18.241	.11	.03	2.80	20.12	76.94
2F	1.114	18.129	18.120	.10	.06	2.79	19.58	77.47
3F	1.958	17.945	17.925	.12	.05	2.81	19.15	77.87
4F	4.152	17.729	17.678	.11	.04	2.83	18.26	78.76
5F	5.994	17.559	17.483	.14	.09	2.85	17.68	79.24
6F	8.984	17.342	17.276	.17	.03	2.88	17.07	79.85
7F	13.981	17.132	17.074	.18	.02	2.89	16.25	80.66
8F	21.030	16.981	16.940	.24	.14	2.91	14.93	81.78
9F	28.009	16.701	16.659	.25	.08	3.01	13.62	83.04
10F	34.987	16.248	16.167	.35	.09	3.01	12.53	84.02

[a] Laboratory numbers of analyses with fresh coal are followed by the suffix F.

TABLE 2.—*Primary data from oxidized coal, in experiment with air.*

Analysis No.	Time elapsed (days).	Volume of gas at 760 mm. and 0° C.		Composition of gas.				
		Before taking sample.	After taking sample.	CO_2.	CO.	CH_4.	O_2.	N_2.
		Liters.	*Liters.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
0Ox[a]	0.000	18.511	.....	0.03	0.00	2.91	20.31	76.75
1Ox	.174	18.442	18.393	.12	−.04	2.61	20.58	76.73
2Ox	1.147	18.345	18.300	.12	+.04	2.58	20.37	76.89
3Ox	8.141	18.226	18.169	.09	−.01	2.62	19.84	77.46
4Ox	15.149	18.117	18.079	.19	+.06	2.59	19.40	77.76
5Ox	22.155	18.003	17.952	.17	+.07	2.61	19.00	78.15
6Ox	37.183	17.792	17.745	.19	+.06	2.64	18.26	78.87

[a] Laboratory numbers of analyses with oxidized coal are followed by the suffix Ox.

TABLE 3.—*Statement of the changes in carbon dioxide, experiments with air.*

FRESH COAL.

Analysis No.	Time elapsed (days).	Volume at 760 mm. and 0° C.			
		After taking sample.	Of sample.	Total withdrawn.	Total evolved from coal.
		C. c.	*C. c.*	*C. c.*	*C. c.*
0F	0.000	5	.....	.....	.....
1F	.184	20	0.06	0.06	15
2F	1.114	19	.05	.11	13
3F	1.958	22	.06	.17	17
4F	4.152	19	.06	.23	14
5F	5.994	24	.07	.30	19
6F	8.984	29	.09	.39	24
7F	13.981	31	.09	.48	26
8F	21.030	41	.12	.60	37
9F	28.009	42	.13	.73	38
10F	34.987	57	.18	.91	53

OXIDIZED COAL.

0Ox	0.000	5	.....	.....	.....
1Ox	.174	22	0.06	0.06	17
2Ox	1.147	22	.06	.12	17
3Ox	8.141	16	.05	.17	11
4Ox	15.149	34	.10	.27	29
5Ox	22.155	31	.09	.36	26
6Ox	37.183	34	.10	.46	29

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TABLE 4.—*Statement of the changes in carbon monoxide, experiments with air.*

FRESH COAL.

Analysis No.	Time elapsed (days).	Volume at 760 mm. and 0° C.			
		After taking sample.	Of sample.	Total withdrawn.	Total evolved from coal.
		C. c.	*C. c.*	*C. c.*	*C. c.*
0F	0.000	0	.....	.....	.....
1F	.184	5	.....	.....	5
2F	1.114	11	.....	.....	11
3F	1.958	9	.....	.....	9
4F	4.152	7	.....	.....	7
5F	5.994	16	.....	.....	16
6F	8.984	5	.....	.....	5
7F	13.981	3	.....	.....	3
8F	21.030	24	.....	.....	24
9F	28.009	13	.....	.....	13
10F	34.987	15	.....	.....	15

OXIDIZED COAL.

0Ox	0.000	0	.....	.....	.....
1Ox	.174	− 7	.....	.....	− 7
2Ox	1.147	+ 7	.....	.....	+ 7
3Ox	8.141	− 2	.....	.....	− 2
4Ox	15.149	+11	.....	.....	+11
5Ox	22.155	+13	.....	.....	+13
6Ox	37.183	+11	.....	.....	+11

TABLE 5.—*Statement of the changes in methane, experiments with air.*

FRESH COAL.

Analysis No.	Time elapsed (days).	Volume at 760 mm. and 0° C.				
		After taking sample.	In sample.	Total withdrawn.	Unabsorbed by coal.	Absorbed by coal.
		C. c.	*C. c.*	*C. c.*	*C. c.*	*C. c.*
0F	0.000	537	.....	0.00	537	0
1F	.184	511	1.46	1.46	512	25
2F	1.114	506	1.45	2.91	509	28
3F	1.958	504	1.46	4.37	507	30
4F	4.152	500	1.47	5.84	506	31
5F	5.994	498	1.48	7.32	505	32
6F	8.984	498	1.50	8.82	507	29
7F	13.981	493	1.50	10.32	503	34
8F	21.030	493	1.51	11.83	505	32
9F	28.009	501	1.57	13.40	504	33
10F	34.987	487	1.57	14.97	502	35

OXIDIZED COAL.

0Ox	0.000	540	.....	.....	540	0
1Ox	.174	480	1.36	1.36	481	59
2Ox	1.147	472	1.34	2.70	475	65
3Ox	8.141	476	1.36	4.06	480	60
4Ox	15.149	468	1.35	5.41	473	67
5Ox	22.155	469	1.36	6.77	476	64
6Ox	37.183	468	1.37	8.14	476	64

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TABLE 6.—*Statement of the changes in oxygen, experiment with air.*

FRESH COAL.

Analysis No.	Time elapsed, days.	Volume at 760 mm. and 0° C.				
		After taking sample.	In sample.	Total withdrawn.	Unabsorbed by coal.	Absorbed by coal.
		Liters.	*C. c.*	*C. c.*	*Liters.*	*Liters.*
0F	0.000	3.745	.....	.....	3.745	0.000
1F	0.184	3.670	10.5	10.5	3.681	0.036
2F	1.114	3.548	10.2	20.7	3.561	0.184
3F	1.958	3.433	10.0	30.7	3.464	0.281
4F	4.152	3.228	9.5	40.2	3.268	0.477
5F	5.994	3.091	9.2	49.4	3.140	0.605
6F	8.984	2.949	8.9	58.3	3.007	0.738
7F	13.981	2.775	8.5	66.8	2.842	0.903
8F	21.030	2.529	7.8	74.6	2.604	1.141
9F	28.009	2.269	7.1	81.7	2.351	1.394
10F	34.987	2.026	6.5	88.2	2.114	1.631

OXIDIZED COAL.

0Ox	0.000	3.762	.....	.....	3.762	0.000
1Ox	0.174	3.785	10.7	10.7	3.796	−0.034
2Ox	1.147	3.728	10.6	21.3	3.749	+0.013
3Ox	8.141	3.605	10.3	31.6	3.637	0.125
4Ox	15.149	3.507	10.1	41.7	3.549	0.213
5Ox	22.155	3.411	9.9	51.6	3.463	0.299
6Ox	37.183	3.240	9.5	61.1	3.301	0.461

TABLE 7.—*Statement of the changes in nitrogen, experiment with air.*

FRESH COAL.

Analysis No.	Time elapsed, days.	Volume at 760 mm. and 0° C.				
		After taking sample.	In sample.	Total withdrawn.	Unabsorbed by coal.	Absorbed by coal.
		Liters.	*C. c.*	*C. c.*	*Liters.*	*Liters.*
0F	0.000	14.148	.....	.....	14.148	0.000
1F	0.184	14.035	40	40	14.075	0.073
2F	1.114	14.036	40	80	14.116	0.032
3F	1.958	13.958	41	121	14.079	0.069
4F	4.152	13.923	41	162	14.085	0.063
5F	5.994	13.854	41	203	14.057	0.091
6F	8.984	13.795	42	245	14.040	0.108
7F	13.981	13.772	42	287	14.059	0.089
8F	21.030	13.854	42	329	14.183	−0.035
9F	28.009	13.834	43	372	14.206	−0.048
10F	34.987	13.584	44	416	14.000	0.148

OXIDIZED COAL.

0Ox	0.000	14.212	.....	.....	14.212	0.000
1Ox	0.174	14.113	40	40	14.153	0.059
2Ox	1.147	14.071	40	80	14.151	0.061
3Ox	8.141	14.074	40	120	14.194	0.018
4Ox	15.149	14.058	40	160	14.218	−0.006
5Ox	22.155	14.029	41	201	14.230	−0.018
6Ox	37.183	13.995	41	242	14.237	−0.025

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CONCLUSIONS FROM EXPERIMENTS WITH AIR.

Carbon dioxide, as has been well established,[a] is evolved from coal during its oxidation at ordinary temperatures. Carbon monoxide likewise is evolved from coal under similar conditions, as shown by the work of Mahler[b] on the oxidation of coal. The quantities of carbon monoxide formed were almost within the limits of determination by the method of analysis used. However, the figures indicate that the evolution corresponds with the amount of oxidation which the coal undergoes.

Oxygen is absorbed in these experiments in a manner previously observed by the various investigators—Porter and Ralston,[c] Winmill,[d] and others—already cited. It is to be noted that there are indications that during the first hours of contact between the coal and the methane, oxygen is evolved by the coal while methane is absorbed.

Nitrogen is not absorbed or evolved by the coal in amounts capable of being determined by the method used in the experiment.

Methane is absorbed by Pittsburgh coal in small amounts, 0.08 to 0.16 c. c. per gram of coal, during the first few hours under the conditions investigated; thereafter there is little or no absorption or evolution of methane from the coal, although changes as regards carbon dioxide, carbon monoxide, and oxygen continue. Fresh coal absorbed about half as much methane as that which had been exposed and had evolved the more methane, indicating an equilibrium between methane and coal.

EXPERIMENTS WITH AN ATMOSPHERE OF NITROGEN.

APPARATUS.

In figure 3, *a* is a bottle of about 600 c. c. capacity, in which the coal *b*, and a tube of water, *c*, to keep the atmosphere within the bottle saturated, were placed. Through a millimeter tube the bottle communicated with the sensitive olive-oil manometer *d*. The opposite side of the manometer communicated with the large trapped volume of gas and the water in the closed tube *e*. The trapped air and manometer formed a compensator to correct for changes in the atmosphere in the bottle due to temperature variations. The bottle and the tube *e* were immersed in the water bath *f*. Air was bubbled through the water to cause a circulation in the bath.

The bottle connected with the calibrated burette *g* through the capillary tube *h* and the various cocks. Also connected with the

[a] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Tech. Paper 2, Bureau of Mines, 1911, 14 pp. Winmill, T. F., The absorption of oxygen by coal: Coll. Guard., vol. 108, 1914, pp. 564–567.

[b] Mahler, M. P., De l'action de l'air sur la houille: Compt. rend., t. 150, 1910, pp. 1521–1523.

[c] Porter, H. C., and Ralston, O. C., A study of the oxidation of coal: Tech. Paper 65, Bureau of Mines, 1914, 30 pp.

[d] Winmill, T. F., The absorption of oxygen by coal: Coll. Guard., vol. 106, 1913, pp. 626, 627.

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burette was the olive-oil manometer *i*, in the further arm of which was the trapped volume of gas *j* to serve as compensator for the burette. A few cubic centimeters of water was kept in the burette and its compensator, both of which were inclosed in a water jacket.

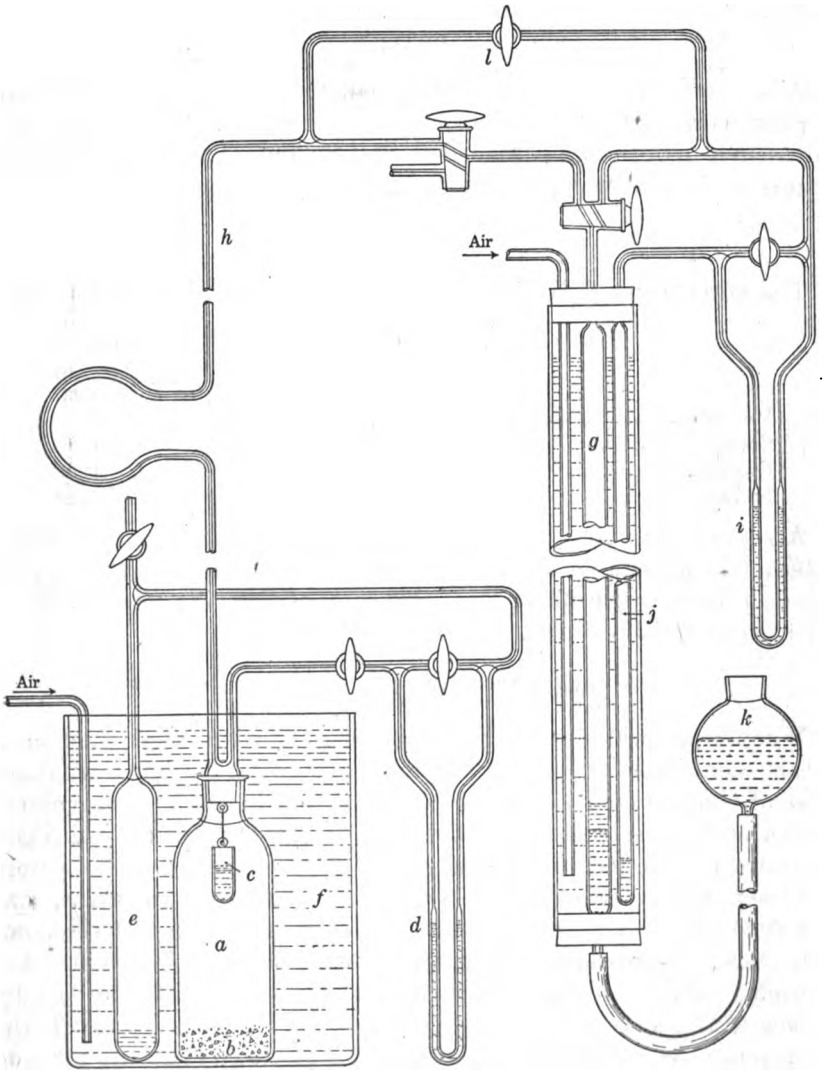

FIGURE 3.—Apparatus used in experiments with atmosphere of nitrogen.

The water in the jacket was made to circulate by means of air bubbles. At the bottom the burette connected with the leveling bulb *k* which contained mercury. The by-pass *l* above the burette allowed all parts of the apparatus to be evacuated and filled simultaneously

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with gas. Connections between all parts of the apparatus were of sealed glass.

The entire volume of the apparatus communicating with the coal, measured from the level of the oil in the manometer on the one side to the level of the oil in the other manometer, was carefully determined.

COAL.

A selected lump of Pittsburgh coal, from the Bureau of Mines experimental mine at Bruceton, Pa., which had been exposed to room air for five months was crushed to pass a 200-mesh sieve. Then 50 grams of the coal was put into the bottle for experiment.

GAS.

The burette was filled with methane of the following composition:

Composition of methane used in experiment.

[Analyst, G. W. Jones.]

	Per cent.
Methane	98.8
Carbon dioxide	0.02
Oxygen	0.01
Nitrogen	1.17

All the remaining parts of the apparatus were then five times alternately avacuated to about 20 millimeters and refilled to atmospheric pressure with nitrogen of this composition: Nitrogen 99.8 per cent, oxygen 0.2 per cent.

ABSORPTION OF THE METHANE.

When equilibrium with the newly introduced nitrogen had been established, both as regards the temperature of the apparatus and that of the nitrogen which the coal itself would absorb, the volume of methane in the burette was measured at the pressure of the nitrogen in contact with the coal. Thereafter all measurements made were automatically referred to the temperature and pressure existing at the time of this first measurement, through the agency of the compensators. Immediately after its volume had been determined the methane was mixed with the nitrogen in contact with the coal by means of the mercury and the leveling bulb. Then at intervals the contraction in volume was read on the burette. These results and those following are given in Table 8 and are represented graphically in figure 4.

At first there was a comparatively rapid absorption of gas. In the course of a couple of hours a maximum was reached and an evolution of gas commenced. This evolution continued for about a week before comparative constancy was reached. Thereafter the total

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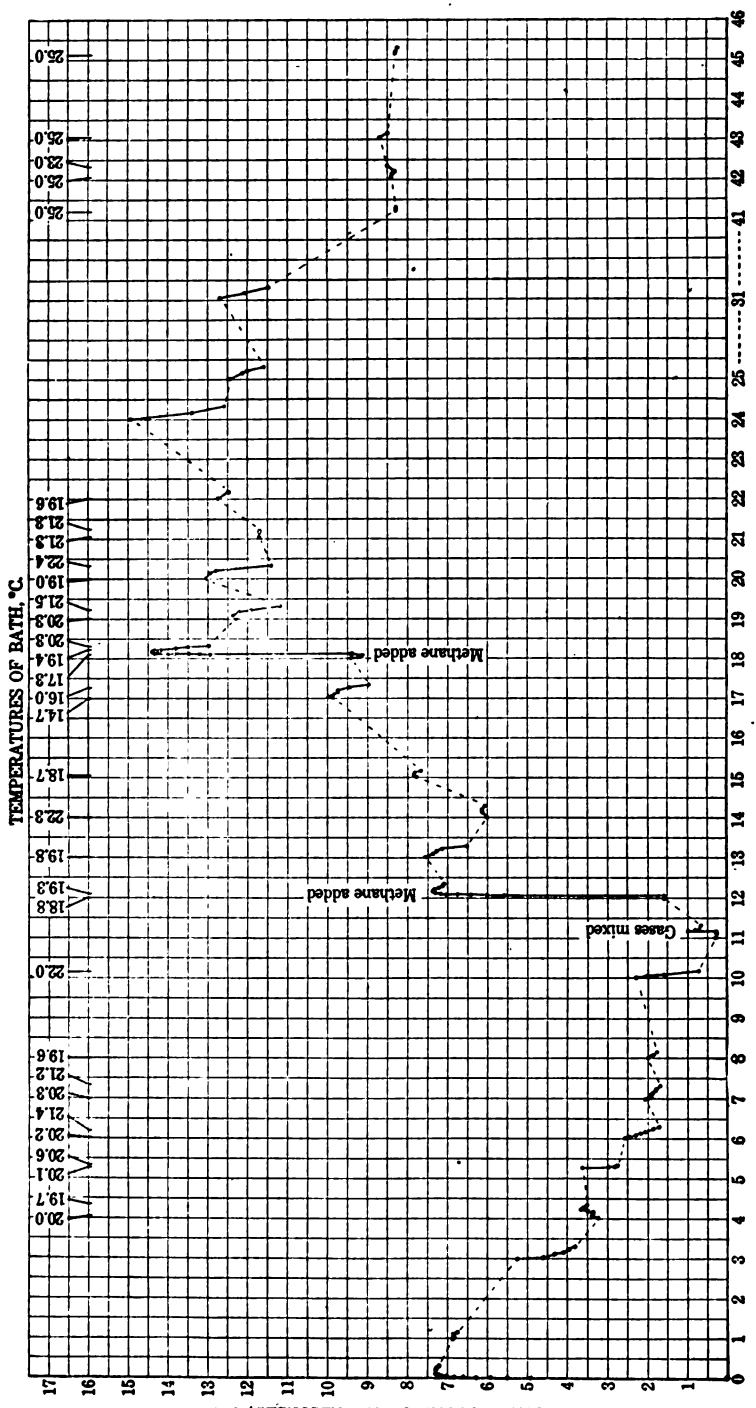

FIGURE 4.—Curve showing relations between time and total volume of gas absorbed, experiment with nitrogen.

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volume of gas in the apparatus was seen to increase with the rise and to decrease with the fall of the room temperature.

On the twelfth day of exposure of coal and methane the mixed gas was withdrawn from the burette for analysis. Results of analyses are given in Table 9. The burette was again filled with the methane as before, the pure methane was mixed with the residual gas in the apparatus, and the changes in volume were followed. Again there was a rapid absorption of gas, which soon reached a maximum, and was followed by a series of decreases and increases in volume, as were noted before.

Six days later the mixed gas in the burette was taken for analysis, replaced by pure methane, and the partial pressure of the methane in contact with the coal was further increased by mixing the gases. The changes that followed were the same as those previously observed.

To overcome changes in the system due to temperature variations, a small thermostat applied to the water bath kept the temperature within 0.2° of 25° C. Keeping the gas and coal for a few hours at this temperature brought the volume of the gas to a point of constancy. Allowing the temperature to change and bringing it to constancy at 25° C. on other days brought the gas back to the same point of equilibrium. The composition of the gas in equilibrium with the coal at 25° C. was determined.

COMPUTATIONS.

From the analyses of the gas and the known volumes in the apparatus the amounts of methane and the other gaseous constituents absorbed or evolved by the coal were computed. A statement of these changes is given in Table 10.

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TABLE 8.—*Data from experiment with atmosphere of nitrogen.*

Time elapsed.		Volume of gas absorbed.	Temperature of bath.	Time elapsed.		Volume of gas absorbed.	Temperature of bath.
Hours and minutes.	Days.			Hours and minutes.	Days.		
Hrs. min.		*C. c.*	*° C.*	*Hrs. min.*		*C. c.*	*° C.*
0	0.0000	0.00	.....	.....	12.0797	6.03	.....
8	0.0056	4.91	.....	.....	12.0832	6.43	.....
13	.0090	5.50	.....	.....	12.0908	6.78	19.3
19	.0132	5.92	.....	.....	12.1006	7.06	.....
28	.0194	6.28	.....	.....	12.1117	7.19	.....
40	.0278	6.60	.....	.....	12.1290	7.34	.....
54	.0375	6.83	.....	.....	12.1568	7.39	.....
1 12	.0500	7.02	.....	.....	12.1957	7.36	.....
1 39	.0698	7.19	.....	.....	12.2464	7.24	.....
2 08	.0889	7.23	.....	.....	12.3047	7.16	.....
2 41	.1118	7.30	.....	.....	12.3346	7.13	.....
3 15	.1354	7.30	.....	.....	13.0138	7.56	19.8
4 21	.1813	7.31	.....	.....	13.1179	7.36	.....
5 54	.2458	7.28	.....	.....	13.1540	7.33	.....
7 20	.3056	7.23	.....	.....	13.2061	7.14	.....
.....	.9965	6.87	.....	.....	13.3263	6.53	.....
.....	1.0250	6.83	.....	.....	14.0082	6.01	22.3
.....	1.0500	6.85	.....	.....	14.1533	6.14	.....
.....	1.0910	6.85	.....	.....	14.2263	6.14	.....
.....	1.1451	6.75	.....	.....	14.3131	6.06	.....
.....	2.9965	5.26	.....	.....	15.0103	7.78	.....
.....	3.0604	4.62	.....	.....	15.0756	7.84	18.7
.....	3.1285	4.34	.....	.....	15.1207	7.81	.....
.....	3.1806	4.10	.....	.....	15.1596	7.66	.....
.....	3.2306	3.95	.....	.....	17.0186	9.86	14.7
.....	3.3090	3.71	.....	.....	17.0471	9.96	.....
.....	4.0090	3.27	.....	.....	17.1103	9.84	.....
.....	4.0521	8.39	20.0	.....	17.1603	9.74	.....
.....	4.0840	3.38	20.0	.....	17.1929	9.74	.....
.....	4.1326	3.38	19.6	.....	17.2714	9.44	16.0
.....	4.1743	3.50	19.3	.....	17.3394	8.96	.....
.....	4.2299	3.67	19.5	.....	18.0089	9.43	.....
.....	4.2674	3.61	19.6	.....	18.0304	9.25	.....
.....	4.3160	3.52	19.7	.....	18.0638	9.16	(a)
.....	5.2688	3.62	20.1	.....	18.0714	9.41	(b)
.....	5.2889	2.98	20.3	.....	18.0900	9.41	(c)
.....	5.3000	2.81	20.5	.....	18.0956	12.93	.....
.....	5.3160	2.76	20.6	.....	18.0983	13.20	.....
.....	6.0076	2.58	20.2	.....	18.1011	13.48	.....
.....	6.0278	2.50	20.5	.....	18.1067	13.83	.....
.....	6.0625	2.45	20.7	.....	18.1143	14.08	.....
.....	6.1013	2.29	20.9	.....	18.1261	14.27	.....
.....	6.1410	2.17	21.2	.....	18.1380	14.33	.....
.....	6.1847	2.08	21.4	.....	18.1518	14.37	17.3
.....	6.2681	1.84	.....	.....	18.1615	14.35	.....
.....	6.3174	1.70	.....	.....	18.1872	14.21	.....
.....	6.9965	2.09	20.3	.....	18.2421	13.81	19.4
.....	7.0167	1.98	20.3	.....	18.2803	13.50	.....
.....	7.0500	1.91	20.3	.....	18.3275	12.96	20.3
.....	7.1035	1.93	20.5	.....	19.0317	12.29	20.3
.....	7.1368	1.90	20.7	.....	19.0907	12.39	.....
.....	7.1945	1.80	20.8	.....	19.1532	12.20	.....
.....	7.2465	1.76	21.0	.....	19.2012	11.91	21.5
.....	7.3097	1.68	21.2	.....	19.3365	11.18	.....
.....	8.0035	2.00	19.6	.....	20.0185	13.06	19.0
.....	8.0264	1.98	.....	.....	20.1511	12.91	.....
.....	8.0542	1.92	.....	.....	20.1908	12.65	.....
.....	8.0972	1.85	.....	.....	20.3275	11.40	22.4
.....	8.1410	1.77	.....	.....	21.0713	11.71	21.3
.....	10.0000	2.29	.....	.....	21.1531	11.71	.....
.....	10.0493	2.02	.....	.....	21.1944	11.71	21.3
.....	10.0903	1.59	.....	.....	22.0386	12.75	19.6
.....	10.3250	.70	22.0	.....	22.1525	12.48	.....
.....	11.0000	.54	.....	.....	24.0351	14.91	.....
.....	11.1493	.50	.....	.....	24.1894	13.41	.....
.....	11.1757	.53	(a)	.....	24.3268	12.61	.....
.....	11.1813	1.00	.....	.....	25.0292	12.41	.....
.....	11.1896	.80	.....	.....	25.1574	12.16	.....
.....	11.2005	.71	.....	.....	25.1984	12.01	.....
.....	11.3160	.70	.....	.....	25.3192	11.61	.....
.....	11.9965	1.58	a 18.8	.....	31.0768	12.70	.....
.....	12.0201	1.58	(b)	.....	31.2053	12.08	.....
.....	12.0700	1.58	(c)	.....	31.3171	11.49	.....
.....	12.0769	5.59	.....				

a Gases mixed.
b Sample of gas taken for analysis.
c Gases mixed with new methane.

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TABLE 8.—*Data from experiment with atmosphere of nitrogen*—Continued.

Time elapsed, days.	Volume of gas absorbed.	Temperature of bath.	Time elapsed, days.	Volume of gas absorbed.	Temperature of bath.
	C.c.	*°C.*		*C.c.*	*°C.*
41.2185	8.29	[a] 25	42.3310	8.49	23
41.2254	8.31	.....	43.0789	8.71	[d] 25.0
41.2622	8.29	.....	43.1608	8.49	.....
41.3386	8.26	(b)	45.1629	8.33	[e] 25.0
42.0886	8.41	[c] 25	45.2094	8.29	.....
42.1560	8.39	.....	45.3133	8.26	(*f*)
42.1879	8.34	.....			

[a] Bath had been at this temperature for 5 hours.
[b] Gases mixed.
[c] For 2 hours.
[d] For ½ hour.
[e] For 4 hours.
[f] Sample of gas taken for analysis.

TABLE 9.—*Results of analyses of the gases, experiment with atmosphere of nitrogen.*

Source of sample.	Day of experiment sample was taken.	Proportion in sample, percentage by volume.			
		CO_2.	CH_4.	O_2.	N_2.
Nitrogen used [a]	.....	0.0	0.0	0.2	99.8
Methane used [b]	.....	.02	98.8	.01	1.2
Gas from apparatus [a]	12.0201	.14	11.12	.14	88.60
Do. [a]	18.0714	.16	21.29	.14	78.41
Do. [a]	45.3133	.16	32.09	.11	67.64

[a] Analysis made by author. [b] Analysis made by G. W. Jones.

TABLE 10.—*Statement of the changes of each constituent of the gas, experiment with atmosphere of nitrogen.*

Day of experiment.	Volume of gas at 760 mm. and 0° C.			Partial volume of all gas in apparatus.			
	In coal bottle and tubing.	In burette.	Total in apparatus.	CO_2.	CH_4.	O_2.	N_2.
	C.c.	*C.c.*	*C.c.*	*C.c.*	*C.c.*	*C.c.*	*C.c.*
0.0000	583.7	84.93	668.6	0.02	83.91	1.18	583.5
12.0201	583.7	83.35	667.1	.93	74.18	.93	591.1
12.0700	583.7	92.01	675.7	.84	155.8	.83	518.3
18.0718	583.7	84.18	667.9	1.07	142.2	.94	523.7
18.0900	583.7	92.03	675.7	.95	215.2	.83	458.8
45.3133	583.7	93.18	676.9	1.08	217.2	.74	457.9

Day of experiment.	Changes in volume of constituents of gas.					Remarks.
	Total.	CO_2.	CH_4.	O_2.	N_2.	
	C.c.	*C.c.*	*C.c.*	*C.c.*	*C.c.*	
0.0000						Start of experiment.
12.0201	−1.58	+0.91	− 9.73	−0.25	+7.6	Sample of gas taken from burette.
12.0700						Fresh methane in burette mixed with gas.
18.0718	−7.83	+ .23	−13.6	+ .11	+5.4	Sample taken from burette.
18.0900						Fresh methane admixed.
45.3133	+1.15	+ .13	+2.0	− .09	− .9	
Sum of changes during experiment	−8.26	+1.27	−21.3	− .23	+12.1	

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CONCLUSIONS FROM EXPERIMENTS WITH THE NITROGEN ATMOSPHERE.

Carbon dioxide was evolved from the coal in small amounts. The quantities were so small that definite conclusions can not be drawn, but it seems that as the partial pressure of the carbon dioxide was reduced by the replacing of the gas by methane, the coal evolved carbon dioxide in an amount sufficient to maintain a constant pressure of that constituent.

Oxygen was present in minute quantities and did not disappear. No conclusions are warranted from the data at hand.

Nitrogen is shown to be evolved from Pittsburgh coal, previously in equilibrium with the gas, at the time that methane is absorbed. When methane was evolved from the coal through an increase in temperature, some nitrogen was again absorbed. Hence, the equilibrium between nitrogen and coal changes with a change of conditions.

Methane was absorbed to the extent of 0.4 c. c. per gram of Pittsburgh coal from an atmosphere containing 30 per cent of methane and 70 per cent of nitrogen when at 25° C. and atmospheric pressure. The amount of methane absorbed increases with the partial pressure of the gas. The absorption is rapid, and with Pittsburgh coal a state of equilibrium is reached in 2 to 4 hours. Thereafter evolution or absorption of the gas occurs with rise or fall of the temperature.

SUMMARY.

Experiments on the absorption of gases from various mixtures of Pittsburgh bituminous coal pulverized to pass a 200-mesh sieve, both in the fresh and the altered condition due to exposure at ordinary temperatures to air, have established these points:

1. At ordinary temperatures newly mined Pittsburgh coal quickly absorbed methane from an atmosphere of air containing about 3 per cent of admixed methane, the absorption being 0.08 c. c. per gram of coal. After about four hours' contact an equilibrium existed between the methane and the coal, although changes in the coal may continue through absorption of oxygen with resulting oxidation of the coal.

2. Under the same conditions, coal that had been exposed to the action of room air for five weeks, with resulting loss of methane, absorbed 0.16 c. c. or twice as much methane. After about four hours' exposure a condition of equilibrium existed between the coal and the methane.

3. The coal in equilibrium with nitrogen absorbed methane in amounts that increased with increase in the partial pressure of the methane.

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4. With absorption of the methane there was an evolution of nitrogen in amounts somewhat less than the volume of methane absorbed.

5. Nitrogen may be absorbed and evolved by coal; the amount varies with the temperature and the partial pressure of the gas.

6. Coal in equilibrium with a mixture of nitrogen and methane absorbs gas with a fall in temperature and evolves gas with a rise in temperature.

7. If the temperature is held constant at a certain point, then allowed to vary and again held constant at that point, a definite equilibrium between coal and gas is repeatedly established.

8. In so far as investigated, the absorption of gases by Pittsburgh coal is closely analogous to the absorption of gases by charcoal.

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